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Clustering Trinidad Head, CA ozonesonde profiles with self- organizing maps: Links to surface ozone

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Talk Outline

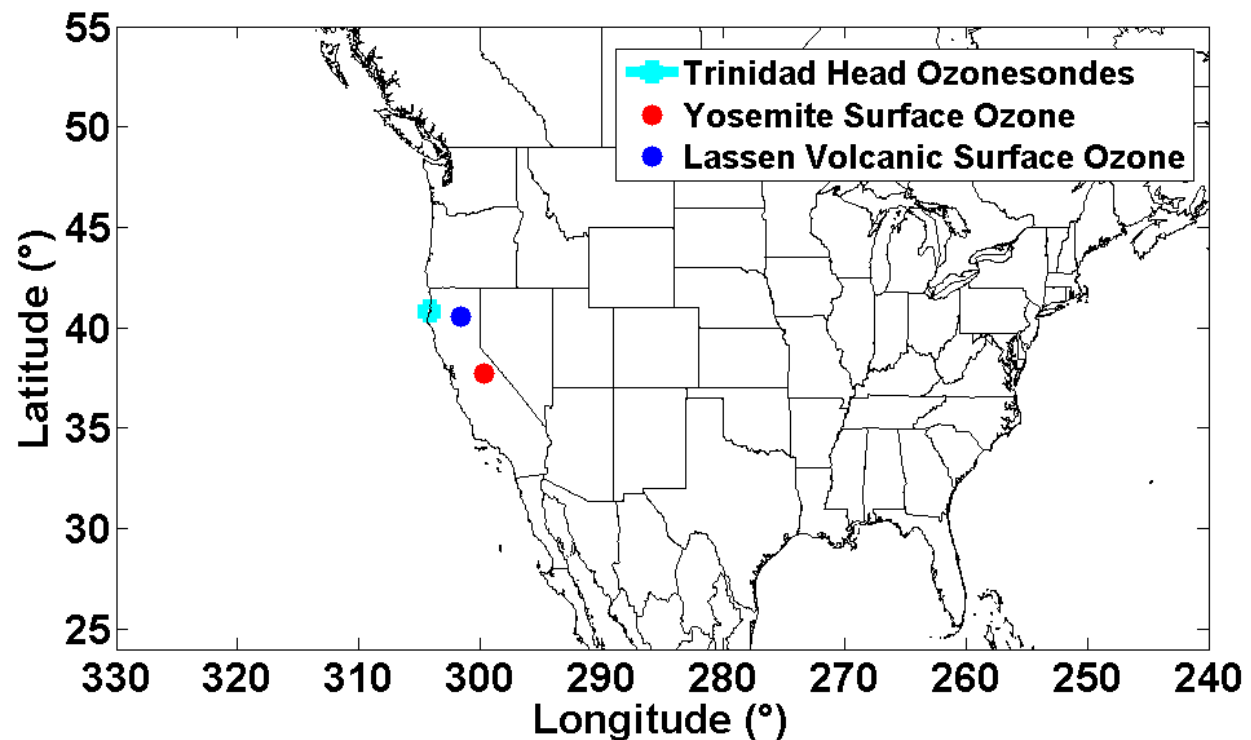
- 1) Tropospheric O₃ transport to Western U.S.
- 2) Why cluster ozonesonde data with self-organizing maps (SOM)?
- 3) Trinidad Head, CA, ozonesonde profile SOM results
- 4) SOM links to surface O₃ observations at two regional elevated sites
- 5) Summary

1) Tropospheric O₃ Transport to Western U.S.

- Main contributors of enhanced tropospheric O₃ are stratosphere-to-troposphere exchange (STE), transport of Asian emissions/imported pollution
- Enhanced free tropospheric O₃ affects surface O₃ measurements
 - STE may contribute to Western U.S. surface O₃ up to 3x more than transport from Asia (Langford et al. 2015; Lin et al. 2012a/b)
 - IONS-2010 ozonesonde network during CalNex campaign: O₃ entering W U.S. affects high-elevation surface O₃ monitors (Cooper et al., 2011)
- What are the statistics of enhanced tropospheric O₃ events over a long-term record, and the links to surface O₃?

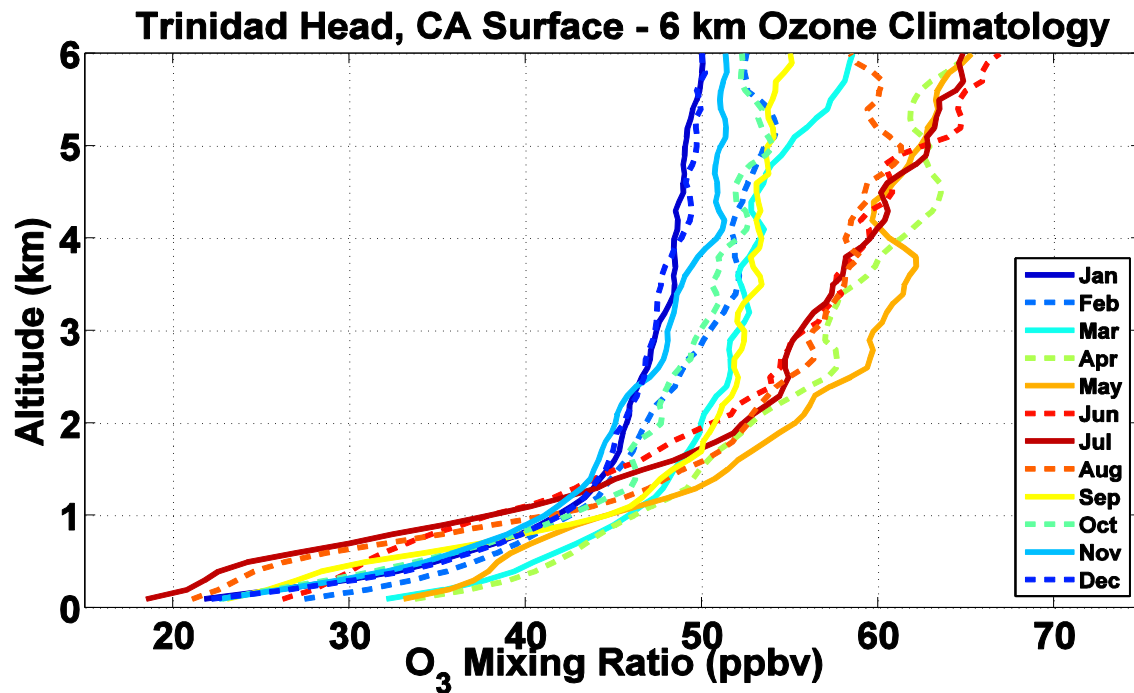
Data – Trinidad Head Sondes, National Park Surface O₃

- Trinidad Head ozonesondes ~once weekly since Aug 1997 (944 launches)
- Excellent location for monitoring tropospheric O₃ entering U.S.
- How is 18-year ozonesonde record linked to surface O₃?
 - Use two surface O₃ monitors from National Parks: **Lassen Volcanic** and **Yosemite** (CASTNET sites)

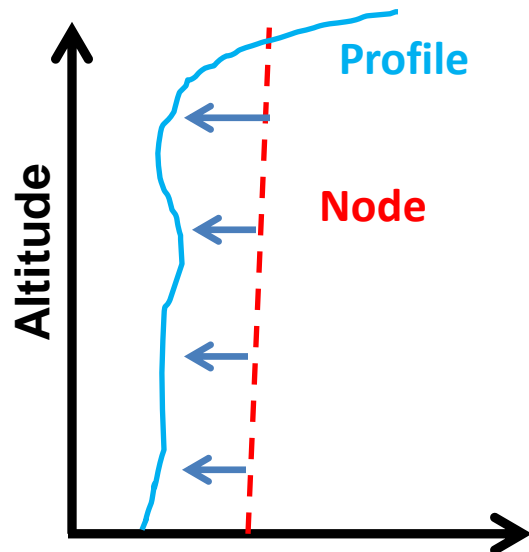


2) Why Cluster Ozonesonde Data with Self-Organizing Maps (SOM)?

- Seasonal/monthly O_3 climatology reveals some information about temporal O_3 changes
- Late spring tropospheric O_3 maximum – STE and imported pollution – not point of this talk
- Approach: 1) Use clusters of O_3 mixing ratio profiles to identify O_3 events at Trinidad Head otherwise masked by climatology**
- 2) Compare Trinidad Head ozonesonde profile clusters to surface O_3 at Lassen Volcanic and Yosemite Parks**

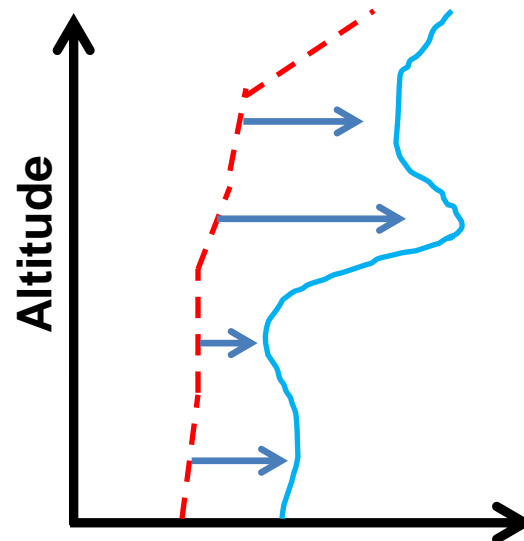


A Brief Primer on SOM



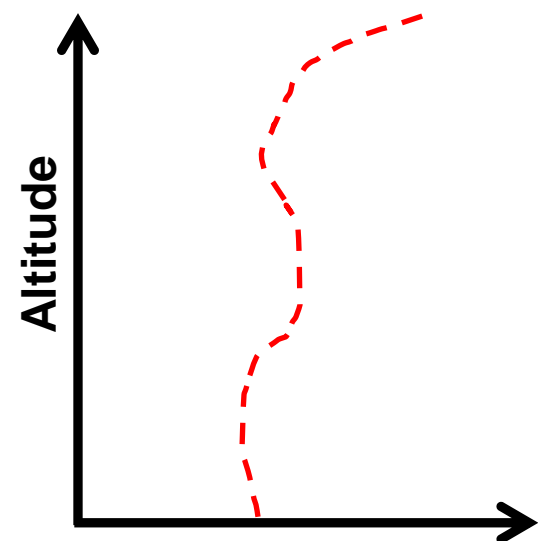
O₃ Mixing Ratio

Feed profile data,
update the node(s)



O₃ Mixing Ratio

Feed more profile data,
update the node(s)



O₃ Mixing Ratio

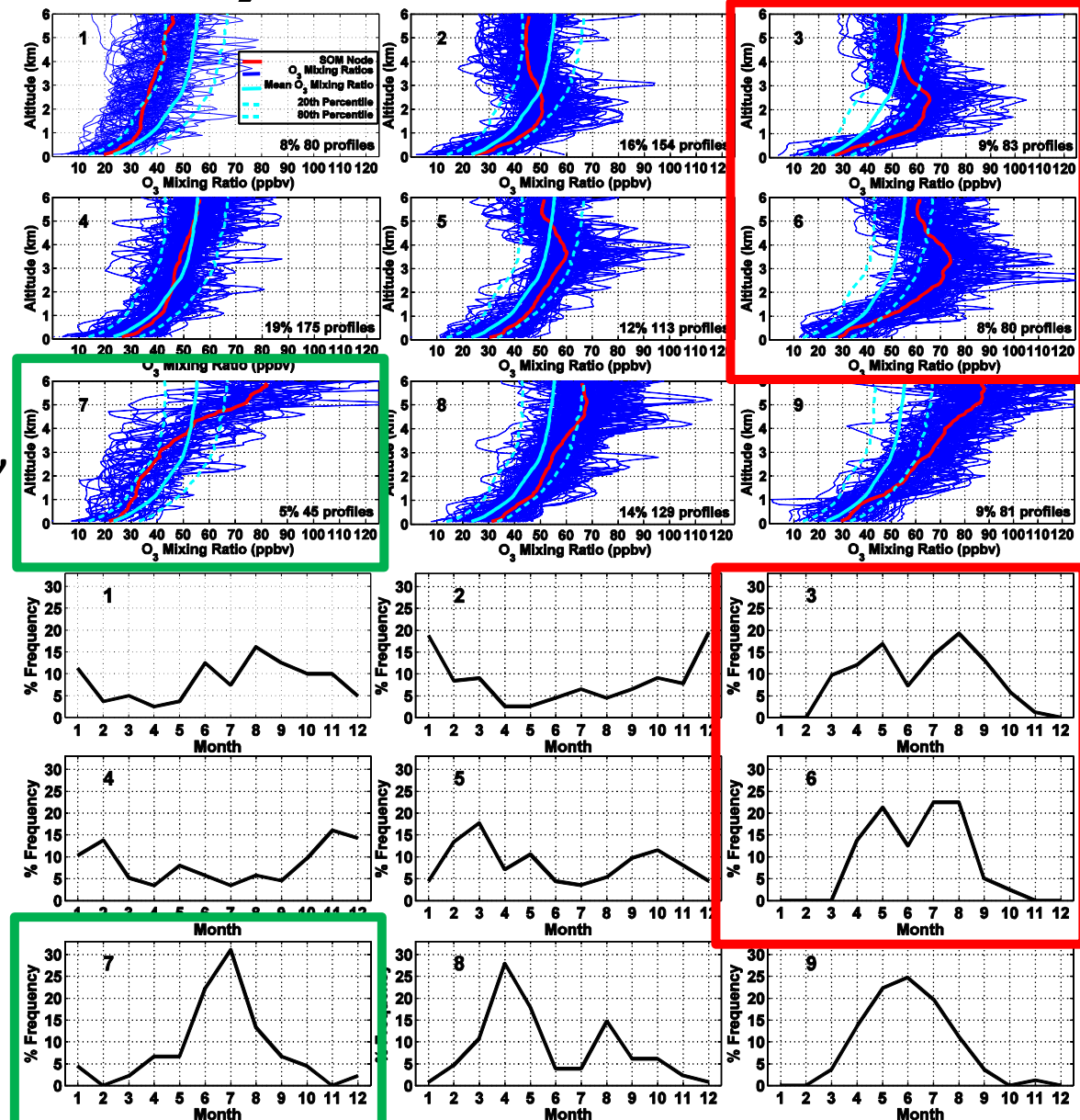
Nodes become more like
input data and representative
of their closest vectors

User chooses number of clusters (represented by “nodes”) and various other inputs

Final Product: Each SOM node is the mean of its member data, map organized with like nodes adjacent in the map

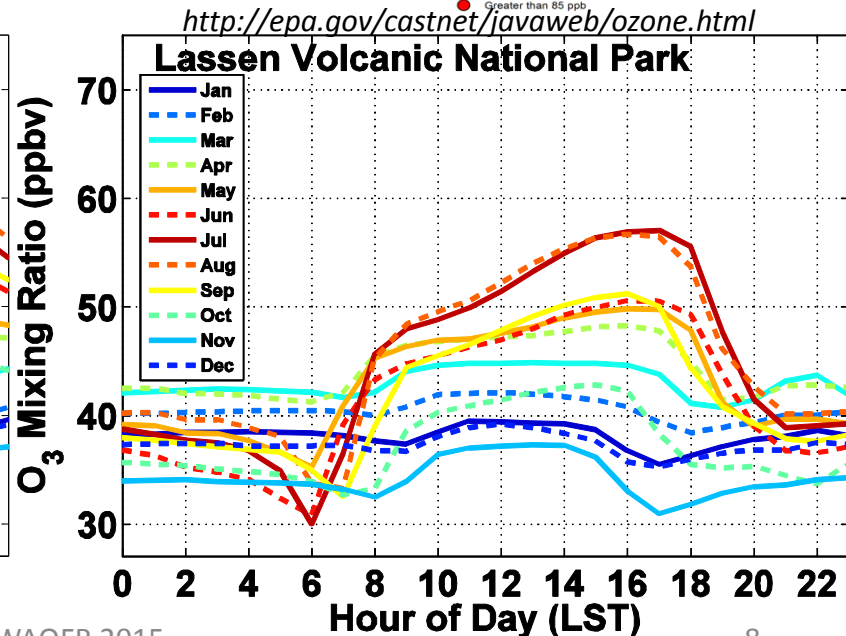
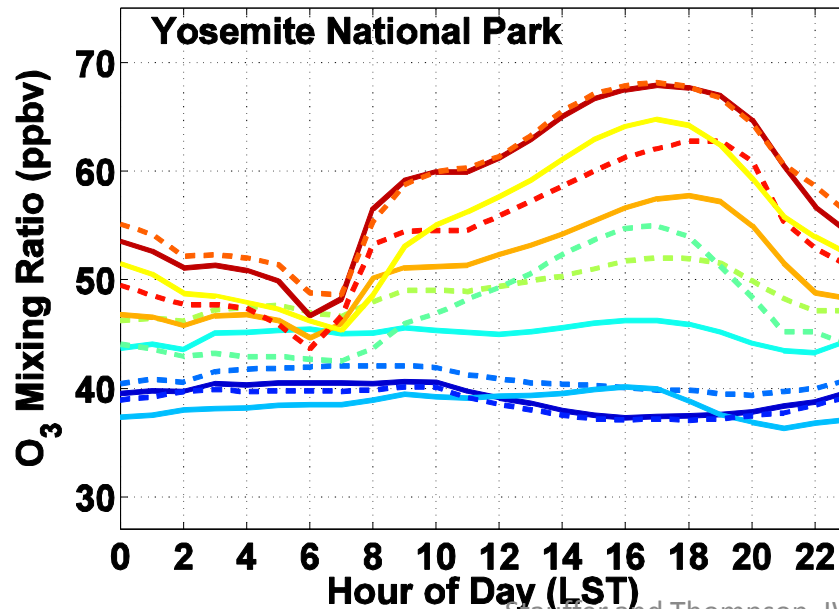
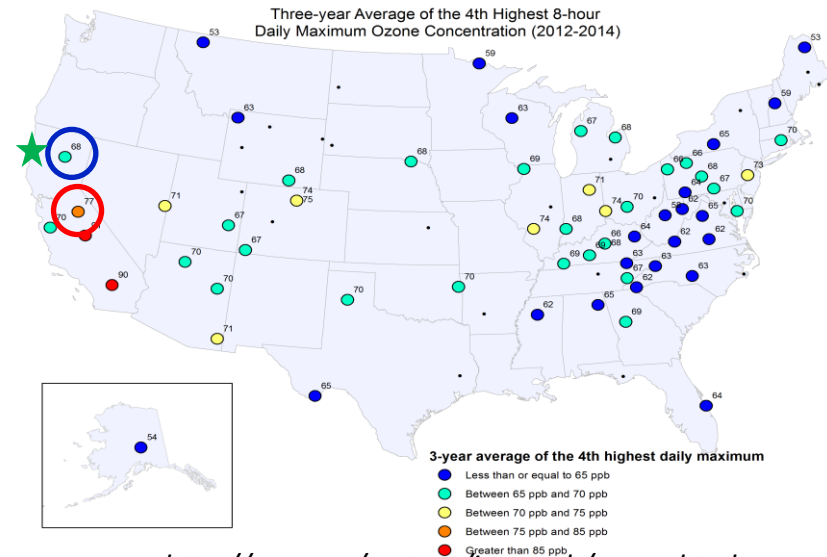
3) Trinidad Head, CA SOM results

- 3x3 SOM (9 clusters) → of surface – 6 km O_3 mixing ratios
- Clean (1, 4, 7, on left) and polluted clusters (3, 6, 9, on right)
- **Seasonality** of profiles in each cluster →
- Focus on clusters with layers of pollution (3 and 6)



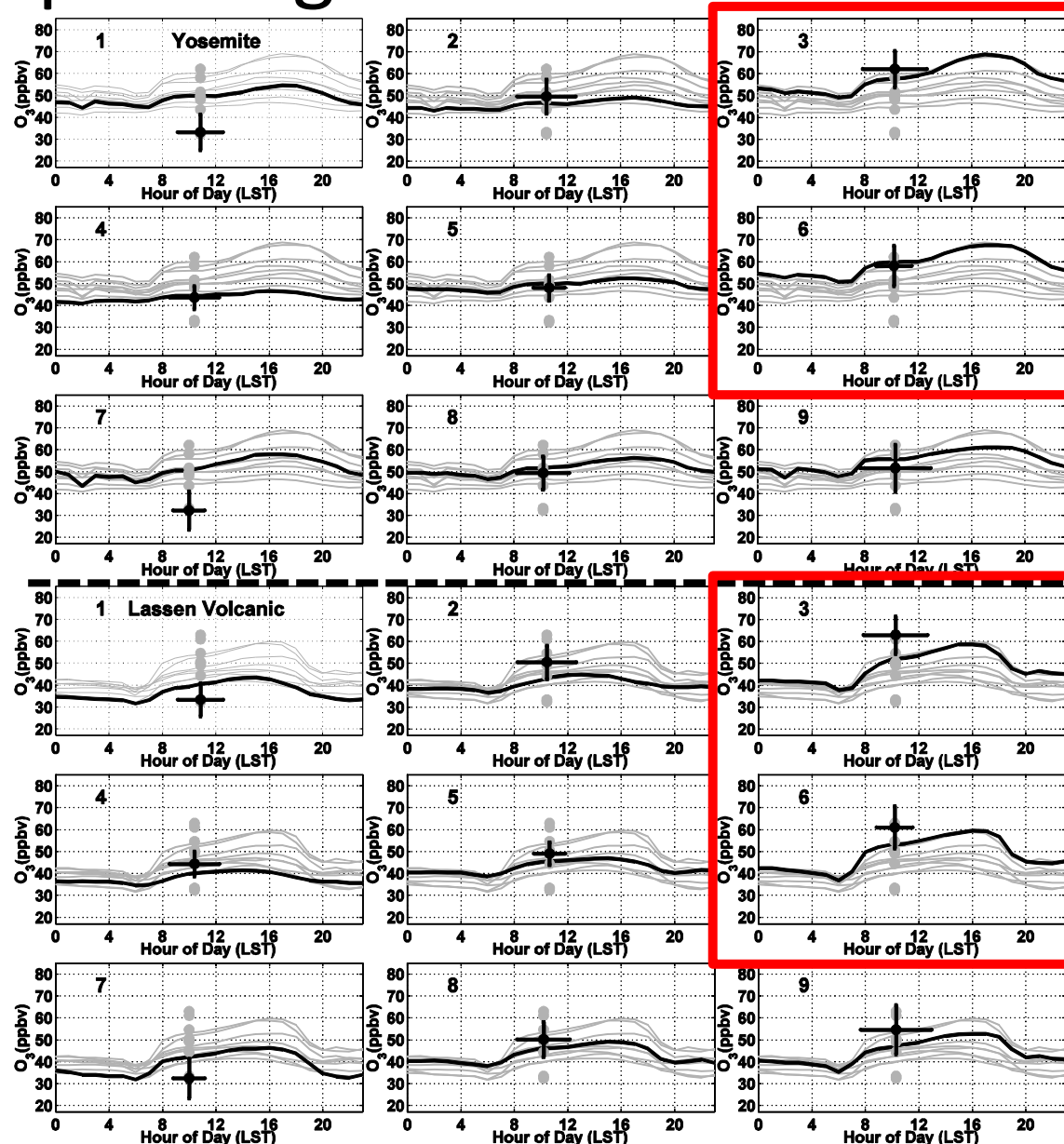
4) SOM links to surface O_3 observations at two long-term elevated sites

- **Yosemite:** 1605 m amsl, 500 km SE of Trinidad Head
- **Lassen Volcanic:** 1756 m amsl, 220 km E of Trinidad Head
- Find the relationship between O_3 profile clusters and the surface



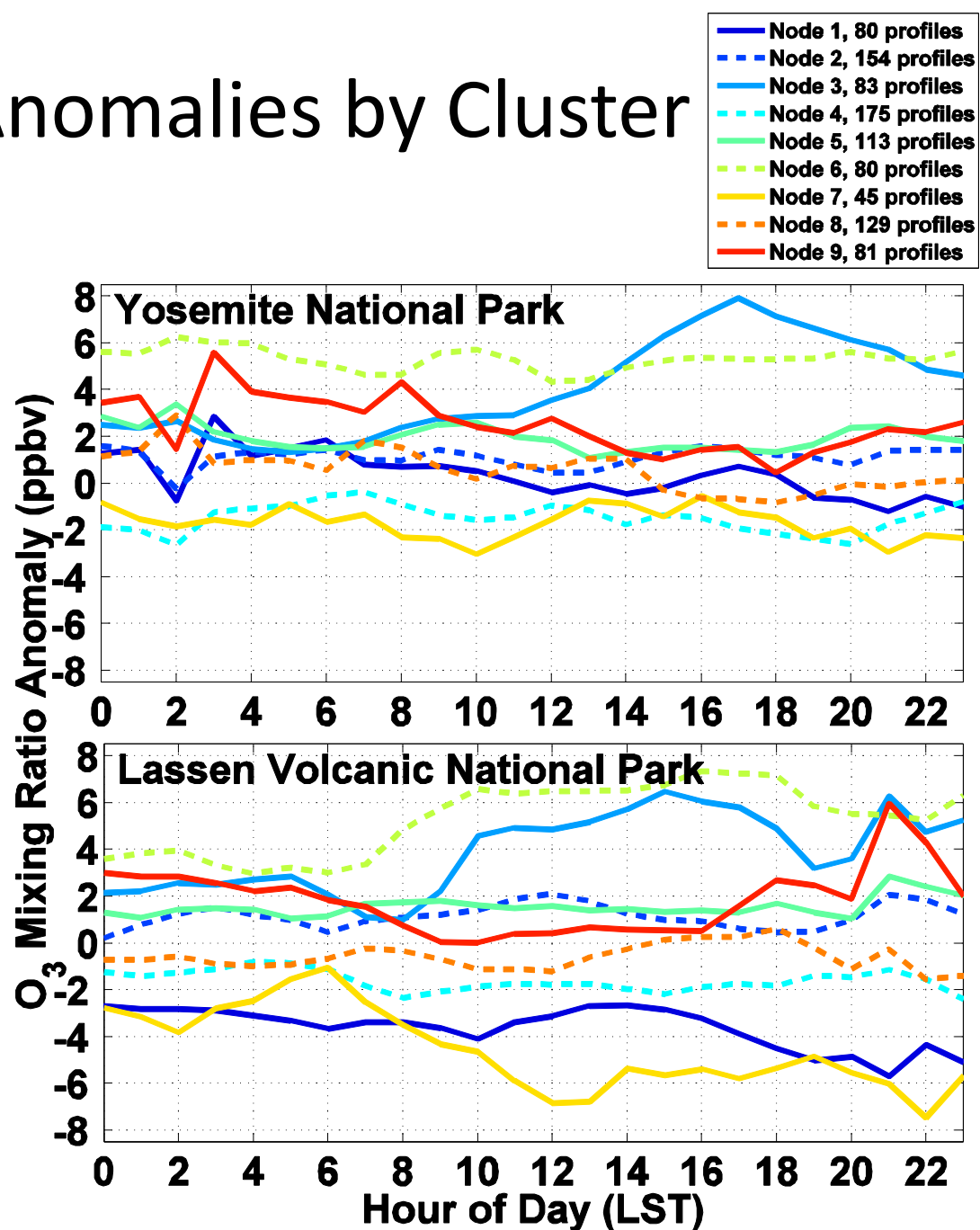
Surface O₃ Corresponding to Sonde Clusters

- **Black Lines** = Average diurnal surface O₃ for days corresponding to SOM cluster (**grey lines** = all clusters plotted)
- **Dots** = Trinidad Head cluster average O₃ $\pm 1\sigma$ from profile at corresponding surface site elevation (**grey dots** = all clusters plotted)
- General agreement between sonde and surface, except clean, summer/fall clusters 1 and 7
- Highest tropospheric O₃ at Trinidad Head = Highest surface O₃ at Lassen Volcanic and Yosemite



Surface O₃ Anomalies by Cluster

- Observed surface O₃ by cluster compared to monthly climatology →
- Clusters 3 and 6: Hourly O₃ averages **6 – 8 ppbv higher than climatology**
- Clustering Trinidad Head O₃ profile identifies anomalous events both for free tropospheric and surface O₃



Consequences for NAAQS/CARB Exceedances – Yosemite

- Sonde/Surface connection established
 - What does it mean for O₃ regulations of MDA8?
- Exceedance rate and number (n) over 18 years, corresponding to Trinidad Head profile clusters
- Lowering of standard to 65 ppbv causes jump in exceedances for clusters 3 and 6
- Yosemite: ~11 → ~15 exceedances/year if CARB AAQS dropped from 70 to 65 ppbv

Yosemite	>75 ppbv (n) (NAAQS)	>70 ppbv (n) (CARB)	>65 ppbv (n)
Cluster 3	31.3 % (26)	38.6 % (32)	54.2 % (45)
Cluster 6	28.8 % (23)	41.3 % (33)	55.0 % (43)
Cluster 7	13.3 % (6)	20.0 % (9)	37.8 % (17)
Cluster 8	7.8 % (10)	15.5 % (20)	24.0 % (31)
Cluster 9	16.0 % (13)	32.1 % (26)	45.7 % (37)

Consequences for NAAQS/CARB Exceedances

– Lassen Volcanic

- Exceedance rate and number (n) over 18 years, corresponding to Trinidad Head profile clusters
- Lowering of standard to 65 ppbv causes jump in exceedances for clusters 3 and 6
- Lassen Volcanic: ~2 → ~4 exceedances/year if CARB AAQS dropped from 70 to 65 ppbv (recall the 68 ppbv O₃ design value)

Lassen Volcanic	>75 ppbv (n) (NAAQS)	>70 ppbv (n) (CARB)	>65 ppbv (n)
Cluster 3	4.8 % (4)	12.0 % (10)	24.1 % (20)
Cluster 6	3.8 % (3)	12.5 % (10)	25.0 % (20)
Cluster 7	0 % (0)	0 % (0)	6.7 % (3)
Cluster 8	0 % (0)	1.6 % (2)	5.4 % (7)
Cluster 9	1.2 % (1)	6.2 % (5)	12.3 % (10)

5) Summary

- Trinidad Head, CA O_3 profile clusters correspond to highest surface O_3 measurements at two National Park (high elevation) O_3 monitors
 - Enhanced tropospheric O_3 measured by Trinidad Head sondes has significant effect on surface O_3 at Lassen Volcanic and Yosemite National Parks
- Majority of NAAQS/CARB O_3 exceedances at both surface sites occurred with Trinidad Head clusters 3 and 6
 - Surface O_3 hourly maxes 6 – 8 ppbv above climatological values
- Next Steps: Separation of STE and imported pollution effects on Trinidad Head sondes, surface O_3

Acknowledgments

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- “Gator” Team: N. Balashov, H. Halliday, S. Miller (at Penn State), D. Kollonige, Z. Fasnacht (at UMD)
- Trinidad Head, CA, station PIs Sam Oltmans and Bryan Johnson (NOAA ESRL GMD)
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- Thank you for your attention

Select References

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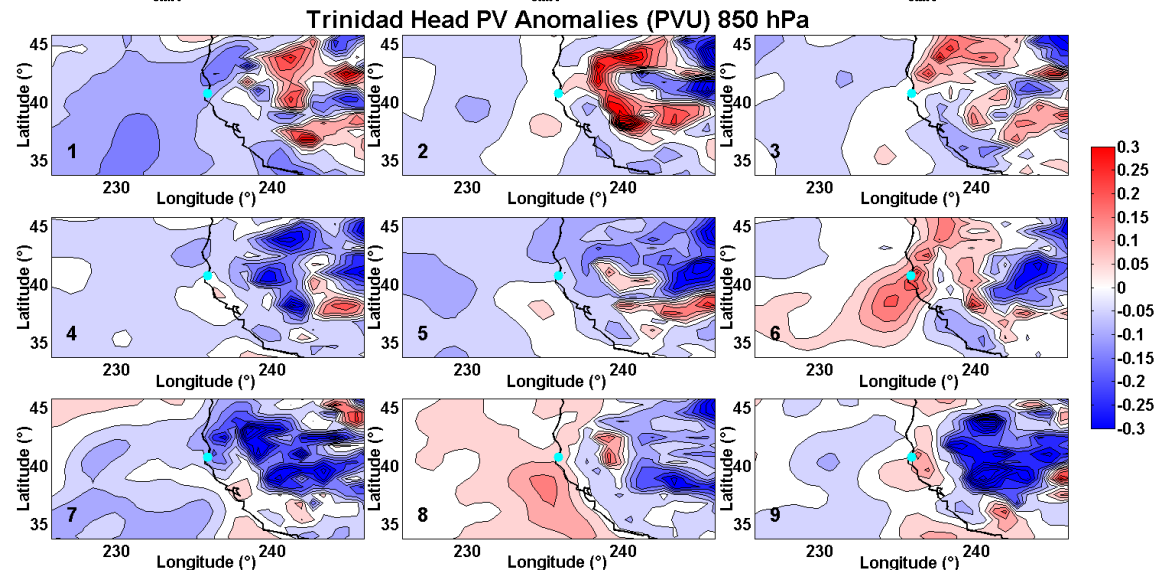
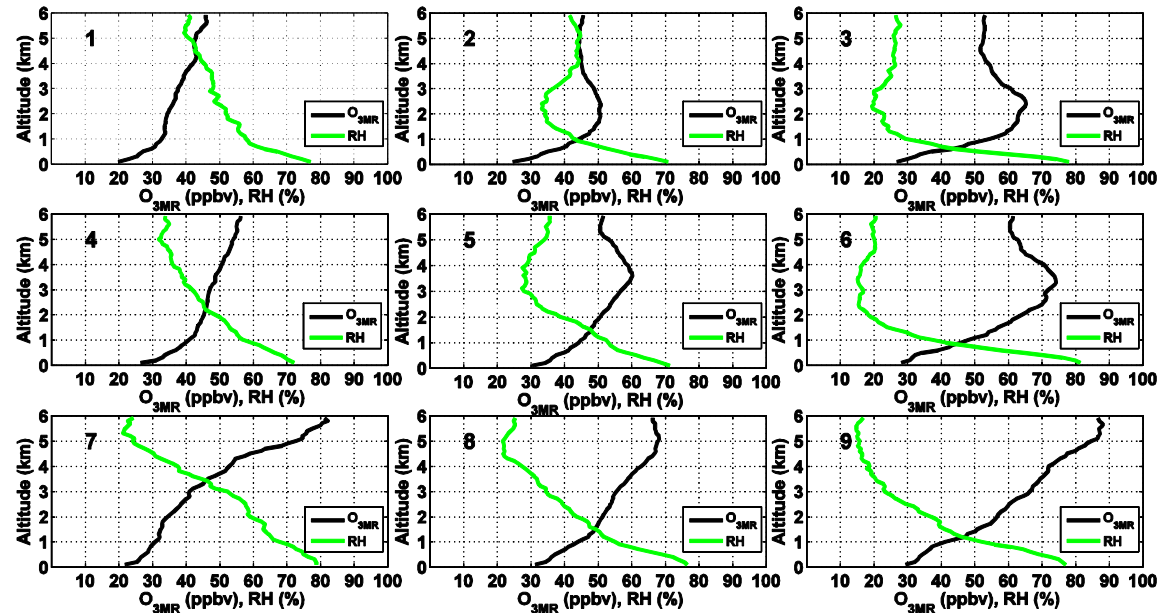
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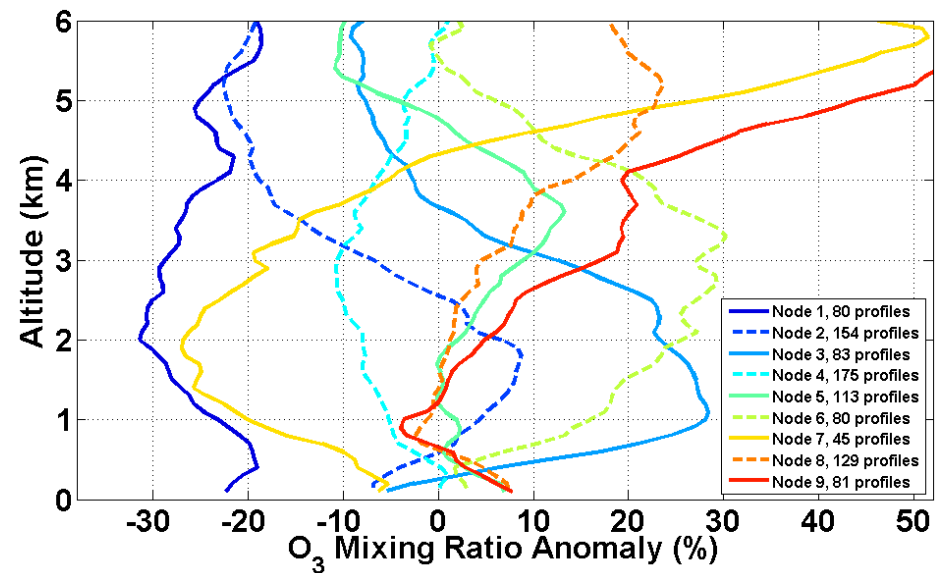
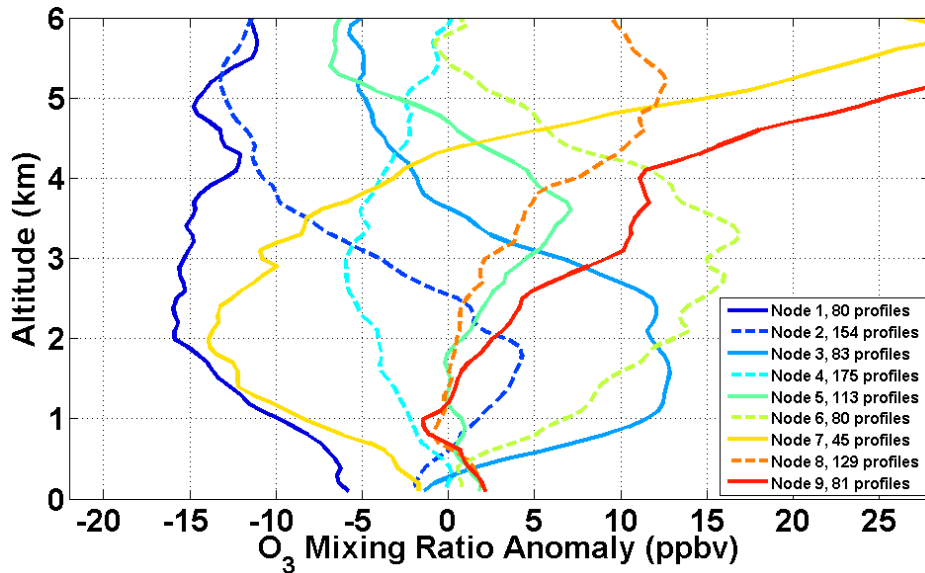
Extras

STE Signatures in Clusters 3 and 6

- Clusters 3 and 6 contain the highest O_3 , and also lowest RH, from 1 – 4 km
- ERA-Interim reanalysis shows anomalously high PV at 850 hPa for both clusters 3 and 6
- More work to sort STE layers from pollution from Asian continent



How do enhanced O_3 layers compare to climatology?



Surface O₃ % Anomalies by Cluster

